METHOD FOR IMPROVING HARD BIAS PROPERTIES OF LAYERS IN A MAGNETORESISTIVE SENSOR

BACKGROUND OF THE INVENTION

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1. Field of the Invention.

This invention relates in general to magnetic storage systems, and more particularly to a method for improving hard bias properties of layers of a magnetoresistance sensor.

10   2. Description of Related Art.

Magnetic recording is a key and invaluable segment of the information-processing industry. While the basic principles are one hundred years old for early tape devices, and over forty years old for magnetic hard disk drives, an influx of technical innovations continues to extend the storage capacity and performance of magnetic recording products.

15 For hard disk drives, the areal density on the magnetic medium has increased by a factor of millions since the first disk drive was applied to data storage. Such increases are based on corresponding improvements in heads, media, drive electronics, and mechanics.

Magnetic recording heads have been considered the most significant factor in areal-density growth. The ability of the magnetic recording heads to both write and subsequently

20 read magnetically recorded data from the medium at data densities well into the gigabits per square inch (Gbits/in^2) range gives hard disk drives the power to remain the dominant storage device for many years to come.

Important components of computing platforms are mass storage devices including magnetic disk and magnetic tape drives, where magnetic tape drives are popular, for

example, in data backup applications. The magnetic disk drive includes a rotating magnetic disk, write and read heads that are suspended by a suspension arm above the rotating magnetic disk and an actuator that swings the suspension arm to place the read and write heads over selected circular tracks on the rotating disk.

5   Read and write heads are directly mounted on a slider that has an Air-Bearing Surface (ABS) between the slider and the rotating disk. The suspension arm biases the slider into contact with the surface of the magnetic disk when the magnetic disk is not rotating. However, when the magnetic disk rotates, air is swirled by the rotating disk adjacent to the ABS causing the slider to ride on a cushion of air just above the surface of the rotating

10   magnetic disk.

         The write and read heads are employed for writing magnetic data to and reading magnetic data from the rotating disk. The read and write heads are connected to processing circuitry that operates according to a computer program to implement the writing and reading functions.

15   A magnetoresistive (MR) sensor detects magnetic field signals through the resistance changes of a sensing element as a function of the strength and direction of magnetic flux being sensed by the sensing element. Conventional MR sensors, such as those used as MR read heads for reading data in magnetic recording disk and tape drives, operate on the basis of the anisotropic magnetoresistive (AMR) effect of the bulk magnetic material, which is

20   typically permalloy. A component of the read element resistance varies as the square of the cosine of the angle between the magnetization direction in the read element and the direction of sense current through the read element. Recorded data can be read from a magnetic medium, such as the magnetic disk in a magnetic disk drive, because the external magnetic

field from the recorded magnetic medium (the signal field) causes a change in the direction of magnetization in the read element, which in turn causes a change in resistance of the read element. This change in resistance may be used to detect magnetic transitions recorded on the recording media.

5   In the past several years, prospects of increased storage capacity have been made possible by the discovery and development of sensors based on the giant magnetoresistance (GMR) effect, also known as the spin-valve effect. In a spin valve sensor, the GMR effect varies as the cosine of the angle between the magnetization of the pinned layer and the magnetization of the free layer. Recorded data can be read from a magnetic medium because

10   the external magnetic field from the recorded magnetic medium, or signal field, causes a change in the direction of magnetization of the free layer, which in turn causes a change in the resistance of the spin valve sensor and a corresponding change in the sensed current or voltage.

          Magnetic sensors utilizing the GMR effect are found in mass storage devices such as, for example, magnetic disk and tape drives and are frequently referred to as spin-valve

15   sensors. The spin-valve sensors are divided into two main categories, the Anti-FerroMagnetically (AFM) pinned spin valve and the self-pinned spin valve. A spin valve includes a pinned layer, a spacer and a free layer. The magnetization of the free layer is free to rotate in response to the presence of external magnetic fields. In an AFM pinned spin

20   valve, the pinned layer has its magnetic moment pinned by a pinning layer. In the self-pinned spin valve, the magnetic moment of the pinned layer is pinned in the fabrication process.

          The magnetic moment of the pinned layer may be pinned via magnetostriction

phenomenon and stress anisotropy. Magnetostriction is the phenomenon in which a

magnetic material changes its size depending on its state of magnetization. External

mechanical stress may also contribute to the state of the magnetic moment. For example, a

positive magnetostriction and compressive stress may be used to pin the pinned layer with

5   the desired magnetic moment orientation. The self-pinned layer may be formed of a single

layer of a single material or may be a composite layer structure of multiple materials. It is

noteworthy that a self-pinned spin valve requires no additional external layers formed

adjacent to the pinned layer to maintain a desired magnetic orientation of the pinned layer

and, therefore, is considered to be an improvement over the anti-ferromagnetically pinned

10   spin valve.

In the construction of a sensor using the GMR effect, a hard magnetic bias structure may be

used to suppress the domain walls movement of the free layer to provide a noise-free

reproducing waveform. This is accomplished by depositing hard magnetic thin films on both

sides of the spin valve layers. A seedlayer structure is typically used to promote the texture

15   of the hard bias films. Chromium is often used as a hard bias seedlayer whereupon the hard

bias layers are grown. However, properties of the hard bias layers degrade significantly

when deposited on spin valve layers. In order to make better junctions, partially milled

sensor structures down to platinum manganese (PtMn) or other spin valve layers have been

considered. The properties of the hard bias layer, however, are degraded significantly on

20   PtMn or on other spin valve layers when deposited using the standard chromium (Cr)

seedlayer.

It can be seen therefore, that there is a need for a method for improving hard bias

properties of layers of a magnetoresistance sensor.

SUMMARY OF THE INVENTION

To overcome the limitations in the prior art described above, and to overcome other limitations that will become apparent upon reading and understanding the present specification, the present invention discloses a method for improving hard bias properties of layers of a magnetoresistance sensor.

The present invention improves the properties of a hard bias layer using a seedlayer structure that includes at least a first layer of silicon and a second layer comprising chromium or chromium molybdenum. Further, benefits are achieved when the seedlayer structure includes a layer of tantalum.

A method for forming of forming a spin valve sensor according to an embodiment of the present invention includes forming a ferromagnetic free layer structure that has a magnetic moment, forming a ferromagnetic pinned layer structure having a magnetic moment, forming a nonmagnetic conductive spacer layer between the free layer structure and the pinned layer structure, forming an anti-ferromagnetic pinning layer coupled to the pinned layer structure for pinning the magnetic moment of the pinned layer structure, forming hard magnetic thin films on both sides of at least a portion of the free layer structure, the ferromagnetic pinned layer structure, the nonmagnetic conductive spacer layer and the anti-ferromagnetic pinning layer and forming a hard bias seedlayer structure adjacent to at least a portion of the free layer structure, the ferromagnetic pinned layer structure, the nonmagnetic conductive spacer layer and the anti-ferromagnetic pinning layer, wherein the forming the hard bias seedlayer structure comprises forming at least a first layer comprising silicon and a second layer comprising chromium or chromium molybdenum.

In another embodiment of the present invention, another method for forming a spin

valve is provided. This method includes forming a spin valve structure including a ferromagnetic free layer, a ferromagnetic pinned layer and an anti- ferromagnetic pinning layer, forming hard magnetic thin films adjacent at least a portion of the spin valve structure on both sides of the spin valve structure and forming a hard bias seedlayer structure adjacent at least a

5   portion of the spin valve structure, wherein the forming the hard bias seedlayer structure comprises forming at least a first layer comprising silicon and a second layer comprising chromium or chromium molybdenum.

In another embodiment of the present invention, a method for forming a seedlayer is provided. This method includes forming a first layer comprising silicon and forming a second

10   layer comprising chromium or chromium molybdenum.

These and various other advantages and features of novelty which characterize the invention are pointed out with particularity to the claims annexed hereto and form a part hereof. However, for a better understanding of the invention, its advantages, and the objects obtained by its use, reference should be made to the drawings which form a further part hereof, and to

15   accompanying descriptive matter, in which there are illustrated and described specific examples of an apparatus in accordance with the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

Fig. 1 illustrates a storage system according to an embodiment of the present invention;

Fig. 2 illustrates one storage system according to an embodiment of the present invention;

Fig. 3 illustrates a slider mounted on a suspension according to an embodiment of the present invention;

Fig. 4 illustrates an ABS view of the slider and the magnetic head according to an embodiment of the present invention;

Fig. 5 illustrates an air bearing surface view of a GMR sensor according to an embodiment of the present invention;

Fig. 6 is a flow chart for providing a seedlayer structure according to embodiments of the present invention that provides significant improvement in the properties of the hard bias layer when deposited on PtMn; and

Fig. 7 is a table showing the hard bias seedlayer structures and hard bias properties on PtMn coated substrates according to embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following description of the exemplary embodiment, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration the specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized as structural changes may be made without departing from the scope of the present invention.

The present invention provides a method for improving hard bias properties of layers of a magnetoresistance sensor. Properties of the hard bias layer are improved using a seedlayer structure that includes at least a first layer of silicon and a second layer comprising chromium or chromium molybdenum. Further, benefits are achieved when the seedlayer structure includes a layer of tantalum.

Fig. 1 illustrates an exemplary storage system 100 according to the present invention. A transducer 110 is under control of an actuator 120, whereby the actuator 120 controls the position of the transducer 110. The transducer 110 writes and reads data on magnetic media 130. The read/write signals are passed to a data channel 140. A signal processor 150 controls the actuator 120 and processes the signals of the data channel 140 for data exchange with external Input/Output (I/O) 170. I/O 170 may provide, for example, data and control conduits for a desktop computing application, which utilizes storage system 100. In addition, a media translator 160 is controlled by the signal processor 150 to cause the magnetic media 130 to move relative to the transducer 110. The present invention is not meant to be limited to a particular type of storage system 100 or to the type of media 130 used in the storage system 100.

Fig. 2 illustrates one particular embodiment of a multiple magnetic disk storage

system 200 according to the present invention. In Fig. 2, a hard disk drive storage system

200 is shown. The system 200 includes a spindle 210 that supports and rotates multiple

magnetic disks 220. The spindle 210 is rotated by motor 280 that is controlled by motor

controller 230. A combined read and write magnetic head 270 is mounted on slider 260 that

5   is supported by suspension 250 and actuator arm 240. Processing circuitry exchanges signals

that represent information with read/write magnetic head 270, provides motor drive signals

for rotating the magnetic disks 220, and provides control signals for moving the slider 260 to

various tracks. Although a multiple magnetic disk storage system is illustrated, a single

magnetic disk storage system is equally viable in accordance with the present invention.

10   The suspension 250 and actuator arm 240 position the slider 260 so that read/write

magnetic head 270 is in a transducing relationship with a surface of magnetic disk 220.

When the magnetic disk 220 is rotated by motor 280, the slider 240 is supported on a thin

cushion of air (air bearing) between the surface of disk 220 and the ABS 290. Read/write

magnetic head 270 may then be employed for writing information to multiple circular tracks

15   on the surface of magnetic disk 220, as well as for reading information therefrom.

Fig. 3 is a diagram 300 that illustrates a slider 320 mounted on a suspension 322.

First and second solder connections 302 and 308 connect leads from the sensor 318 to leads

310 and 314, respectively, on suspension 322 and third and fourth solder connections 304

and 306 connect to the write coil (not shown) to leads 312 and 316, respectively, on

20   suspension 322.

Fig. 4 is an ABS view of slider 400 and magnetic head 410. The slider has a center

rail 420 that supports the magnetic head 410, and side rails 430 and 460. The support rails

420, 430 and 460 extend from a cross rail 440. With respect to rotation of a magnetic disk,

the cross rail 440 is at a leading edge 450 of slider 400 and the magnetic head 410 is at a

trailing edge 470 of slider 400.

The above description of a typical magnetic recording disk drive system, shown in the

accompanying Figs. 1-4, is for presentation purposes only. Storage systems may contain a

5   large number of recording media and actuators, and each actuator may support a number of

sliders. In addition, instead of an air-bearing slider, the head carrier may be one that

maintains the head in contact or near contact with the disk, such as in liquid bearing and

other contact and near-contact recording disk drives.

FIG. 5 illustrates an air bearing surface view of a GMR sensor 500 according to an

10   embodiment of the present invention. GMR heads are very attractive for use as high density

recording magneto resistive (MR) heads because of their high readback output voltages,

linear response, and symmetrical read sensitivity profiles.

In FIG. 5, an air bearing surface view of a GMR sensor 500 including end regions

512 and 514 separated by a central region 516 is shown. A free layer (free ferromagnetic

15   layer) 518 is separated from a pinned layer (AP-pinned ferromagnetic layer) 520 by a non-

magnetic, electrically-conducting spacer layer 522 (typically, primarily copper). The

magnetization of the pinned layer 520 may be fixed through exchange coupling with an

antiferromagnetic (AFM) layer 524. The magnetization of the free layer 518, however, is

free to rotate in the presence of an external field. Free layer 518, spacer layer 522, pinned

20   layer 520 and the AFM layer 524 are all formed in the central region 516.

Hard bias layers 526 and 528 formed in the end regions 512 and 514, respectively,

provide longitudinal bias for the free layer 518. A seedlayer structure 550 is provided to

promote the texture and enhance the grain growth of each of the spin valve stack layers.

Leads 530 and 532 formed over hard bias layers 526 and 528, respectively, provide electrical connections for the flow of the sensing current I_s, from a current source 534 to the GMR sensor 500. A signal detector 540, which is electrically connected to the leads 530 and 532, senses the change in resistance of the GMR sensor 500 due to changes induced by the

5   external magnetic field (e.g., the field generated when a field transition on a disk is moved past the GMR sensor 500). A cap (not shown) is optionally provided on the free layer 518.

During the manufacturing of a read/write head for magnetic recording media, the write head may be formed adjacent to the GMR sensor 500. One skilled in the art will realize that during the manufacture of the write head, and during some of the processes

10   involved in manufacturing the GMR sensor 500, itself, high temperature processes have inevitably been involved. (Examples are the photoresist baking of the write head, the annealing of the AFM layer 524 materials on a substrate 510, which is required for some materials, and resetting of the pinned layer 520). At these temperatures, the grain boundaries of adjacent materials tend to become aligned, notably at the junction of the spacer 522 and

15   the free layer 518 and/or at the boundary of the spacer 522 and the pinned layer 520. In this condition, it is very easy for diffusion between such layers to occur. This results in a degradation of the output signal amplitude produced by the GMR sensor 500.

Other constructions of the GMR sensor 500 are possible, and one skilled in the art could readily adapt the present invention for use with such alternative constructions. For

20   example, where pinned layers 520 having multiple layers are used, multiple iterations of the spacer 522 (and diffusion barrier) could also be employed.

Within the sandwich structure of the GMR head sensor, i.e., "sensing free layer", "conducting space layer", and "pinned layer", the magnetization of the free layer 518 is free

to respond to external magnetic field from the media. The magnetization of the pinned layer

520 is pinned at about 90° to the magnetization of the free layer 518. As the conduction

electrons are scattered between the free 518 and pinned 520 layers through the spacer 522,

the electrical resistance of the head changes in response to the angle of the directions of

5   magnetization between the free 518 and pinned 520 layers.

In order to obtain a noise-free reproducing waveform, a hard magnetic bias structure

526, 528 is required to suppress the domain walls movement of the free layer. This is

accomplished by depositing hard magnetic thin films 526, 528 in adjacent to the spin valve

structure 518-524 on both sides. The hard magnetic thin films 526, 528 supply longitudinal

10   magnetic flux to saturate the free layer 518 along its easy axis to a single domain state. A

seedlayer structure 550 is typically used to promote the texture and enhance the grain growth

of each of the layers520, 522, 524, 516.

For hard magnetic thin films 526, 528 to be used in a GMR head, three fundamental

magnetic properties are required in order to prevent Barkhausen noise (due to domain

15   movement, as mentioned above). First, to ensure that a stable reproducing characteristic is

maintained even when an external magnetic field is applied, the hard magnetic bias layers

526, 528 must have large coercive force (H_c). Second, the in-plane remnant magnetization

(M_r) or M_r times thickness M_t) should be large enough, since this is the component of the

hard magnetic bias layers 526, 528 that provides the longitudinal bias flux.

20   If the M_r of the hard magnetic bias layers 526, 528 is less than the M_r of the free layer

518, with the shared abutting junction, longitudinal bias for the free layer 518 is bound to fall

short of supplying the necessary flux. This implies that the squareness (M_r/M_s) of the

hysteresis loop of the hard bias layer along the in-plane direction should be high. Further, in

order to provide the biasing field and prevent noise a hard bias layers 526, 528 having a high

coercivity is needed.

Properties of the hard bias layers 526, 528 degrade significantly when deposited on

spin valve layers. In order to make high areal density heads, partially milled sensor

5   structures have been considered. The properties of the hard bias layers 526, 528, however,

are degraded significantly on PtMn or on other spin valve layers when deposited using the

standard chromium (Cr) seedlayer structure. Therefore, the properties of the hard bias layers

526, 528 are improved using a hard bias seedlayer structure 570 that includes at least a layer

of chromium or chromium molybdenum 572 and a layer 574 of silicon. Further, benefits are

10   achieved when the hard bias seedlayer structure 570 includes a layer of tantalum 576. Those

skilled in the art will recognize that the present invention is not meant to be limited to

thicknesses implied in Fig. 5.

Fig. 6 is a flow chart 600 for providing a seedlayer structure according to

embodiments of the present invention that provides significant improvement in the properties

15   of the hard bias layer when deposited on PtMn or on other spin valve layers. In Fig. 6, a spin

valve seedlayer is formed 610. An anti-ferromagnetic pinning layer is formed over the spin

valve seedlayer 612. A ferromagnetic pinned layer structure that has a magnetic moment is

formed 620. A nonmagnetic conductive spacer layer is formed over the pinned layer

structure 630. A ferromagnetic free layer is formed over the spacer layer 640. A photomask

20   is formed over the spin valve structure to mask the spin valve structure during ion milling

641. At least one of the free layer, spacer layer, pinned layer and anti-ferromagnetic layer is

ion milled 642. A hard bias seedlayer structure is formed, wherein the hard bias seedlayer

structure comprises at least a first layer of silicon and a second layer comprising chromium

or chromium molybdenum 644. The silicon layer may be formed on a layer of tantalum to form a trilayer seedlayer structure. Hard magnetic thin films are formed in an abutting relationship with the free layer structure on both sides of the free layer structure 650.

Referring again to Fig. 5, the hard bias seedlayer structure 570 according to embodiments of the present invention allows partially ion milling the sensor down to the PtMn 524 or other spin valve layers and depositing the hard bias layer 526, 528 to form the junctions. The deposition of the hard bias 526, 528 on PtMn or on other spin valve layers eliminates the thick seedlayer structure requirement for pinned spin valve structures. The hard bias seedlayer structure 570 according to embodiments of the present invention provides significant benefits to form ultra contiguous junctions (i.e., junctions having sharp edges) because it will dramatically reduce the amount of the sidewall deposition. Furthermore, this will significantly reduce the complexity of the ion milling process for pinned spin valve structures. Therefore, the hard bias seedlayer structure 570 includes at least a layer of silicon 572 and a layer 574 comprising chromium or chromium molybdenum. Further, as described above, the silicon layer may be formed on a layer of tantalum 576 to form a trilayer seedlayer structure.

Fig. 7 illustrates a table 700 that shows the hard bias coercivity and the squareness with various seedlayer structure combinations. As seen, the Ta/Si/CrMo seems to provide better H_c and squareness, while all other seedlayers improve the H_c of the hard bias. For example, with standard chromium seedlayer structures, the coercivity and squareness of the hard bias on PtMn coated substrate or on other spin valve layers are approximately 500 Oe and 0.8 respectively.

Referring to Fig. 7, the first structure 710 includes a seedlayer structure of silicon 712

and chromium 714. The coercivity 770 is increased but the effect on the squareness 771 is less significant. The second structure 716 also includes a seedlayer structure of silicon 718 and chromium 720, but with the thickness of the silicon layer 718 increased. When compared to the first structure 710, the coercivity 772 is reduced some, but the squareness

5   773 increases, albeit slightly.

The third structure 722 includes a seedlayer structure of tantalum 724, silicon 726 and chromium 728. When compared to the first structure 710, the coercivity 774 is reduced some, although not as much as in the second structure 716, and the squareness 775 increases significantly. The fourth first structure 730 includes a seedlayer structure of tantalum 732,

10   silicon 734 and chromium 736, with the thickness of the tantalum 732 increased over thickness of the tantalum 724 of the third structure 722. This, reduces both the coercivity 776 and squareness 777.

The fifth structure 738 includes a seedlayer structure of chromium 740, silicon 742 and chromium 744. The coercivity 778 is greater than 1300 Oe, but the squareness 779 is

15   still less than .9. The same is true for the sixth structure 746, which includes a seedlayer structure of chromium 748, silicon 750 and chromium 752, wherein the thickness of the chromium layer 748 is doubled over the chromium layer 740 of the fifth structure 738. The coercivity 780 and the squareness 781 of the sixth structure 746 are about the same as the coercivity 778 and squareness 779 of the fifth structure 738.

20   The seventh 754 and eighth 762 structures show the greatest improvement. The seventh structure 754 includes a seedlayer structure of tantalum 756, silicon 758 and chromium-molybendum 760. The coercivity 782 is increased significantly as is the squareness 783. The eighth structure 762 doubles the thickness of the tantalum layer 764,

but still includes silicon 766 and chromium-molybendum 768. This increases the coercivity 784 slightly, but decreases the squareness 785 slightly.

Accordingly, the properties of the hard bias layer are improved using a seedlayer structure that includes at least a first layer of silicon and a second layer comprising chromium

5   or chromium molybdenum. Further, benefits are achieved when the seedlayer structure includes a layer of tantalum.

The foregoing description of the exemplary embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are

10   possible in light of the above teaching. It is intended that the scope of the invention be limited not with this detailed description, but rather by the claims appended hereto.